MetaTutor: An Intelligent Multi-Agent Tutoring System Designed to Detect, Track, Model, and Foster Self-Regulated Learning

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Abstract. MetaTutor is both (1) a learning tool designed to teach and train students to self-regulate (e.g., by modeling and scaffolding metacognitive monitoring, facilitating the use of effective learning strategies, and setting and coordinating relevant learning goals), and (2) a research tool used to collect trace data on students' cognitive, metacognitive, affective, and motivational processes deployed during learning. In this session we will showcase MetaTutor, an adaptive multi-agent ITS and demonstrate its ability to detect, track, model, and foster self-regulated learning (SRL). In addition, we will also provide: (1) a brief overview of the theoretical and empirical basis of the system; (2) an overview of the system's ability to detect, track, model, and foster learners' SRL; (3) an overview of the data types collected during learning (e.g., concurrent think-alouds, eye-tracking, note taking and drawing, log-files, and facial detection of emotions) and describe how these data are used to (4) make inferences regarding the system's ability to model, scaffold, and foster learners' SRL.

Keywords: self-regulated learning, metacognition, pedagogical agents, measurement, modeling, scaffolding

1 MetaTutor as a Learning Tool

MetaTutor is a multi-agent, adaptive hypermedia learning environment, designed to train, model, and foster students' SRL while learning about the human circulatory system. The primary goal underlying the design of MetaTutor is to investigate how advanced learning technologies (ALTs) can adaptively scaffold learners' SRL while they learn about complex biological topics [1,2]. MetaTutor is grounded in a theory of SRL that views learning as an active, constructive process whereby learners set goals for their learning and then attempt to monitor, regulate, and control their cognitive and metacognitive processes in the service of those goals [3]. More specifically, MetaTutor is based on several theoretical assumptions of SRL that emphasize the role of cognitive, affective, metacognitive, and motivational (CAMM) processes based on

[4-6]. Moreover, there is a fundamental assumption that learners have the potential to monitor and regulate their CAMM processes while developing a conceptual understanding of the science topic (e.g., the human circulatory system). Although all students have the potential to regulate, few students do so effectively, possibly due to inefficient or a lack of cognitive, emotional or metacognitive strategies, and knowledge [7-10].

As a learning tool, MetaTutor has a host of features that embody and foster self-regulated learning (see Figure 1). These include four pedagogical agents (PAs) who guide students through the two-hour learning session and prompt them to engage in planning, monitoring, and strategic learning behaviors. In addition, the agents can provide feedback and engage in a tutorial dialogue in order to scaffold students' selection of appropriate sub-goals, accuracy of metacognitive judgments, and use of particular learning strategies. The system also uses natural language processing (NLP) to allow learners to express metacognitive monitoring and control processes [11]. For example, learners can click on the SRL palette and then choose their level of understanding on a 6-item Likert-scale before receiving a quiz and can also use the interface to summarize a static illustration related to the circulatory system. Additionally, MetaTutor collects information from user interactions with it to provide adaptive feedback on the deployment of students' SRL behaviors. For example, students can be prompted to self-assess their understanding (i.e., system-initiated judgment of learning [JOL]) and are then administered a brief quiz. Results from the self-assessment and quiz allow PAs to provide adaptive feedback according to the calibration between students' confidence of comprehension and their actual quiz performance.

As illustrated in Figure 1, the system's interface layout also supports SRL processes. For example, an embedded SRL palette provides the opportunity for students to initiate an interaction with the system according to the SRL process selected (e.g., summarize their understanding of the topic). Overall, in line with its theoretical foundations, MetaTutor supports and fosters a variety of SRL behaviors including prior knowledge activation, goal setting, evaluation of learning strategies, integrating information across representations, content evaluation, summarization, note-taking, and drawing. Importantly, it also scaffolds specific metacognitive processes such as judgments of learning, feelings of knowing, content evaluation, and monitoring progress towards goals.

2 MetaTutor as a Research Tool

As a research tool, MetaTutor is capable of measuring the deployment of self-regulatory processes through the collection of rich, multi-stream data including: self-report measures of SRL, on-line measures of cognitive and metacognitive processes (via concurrent think-alouds), dialogue of agent-student interactions, natural language processing of help-seeking behavior, physiological measures of motivation and emotions, emerging patterns of effective problem solving behaviors and strategies, facial data on both basic (e.g., anger) and learning-centered emotions (e.g., boredom), and eye-tracking data regarding the selection, organization, and integration of multiple representations of information (e.g., text, diagrams; see Figure 2 for a typical set-up).
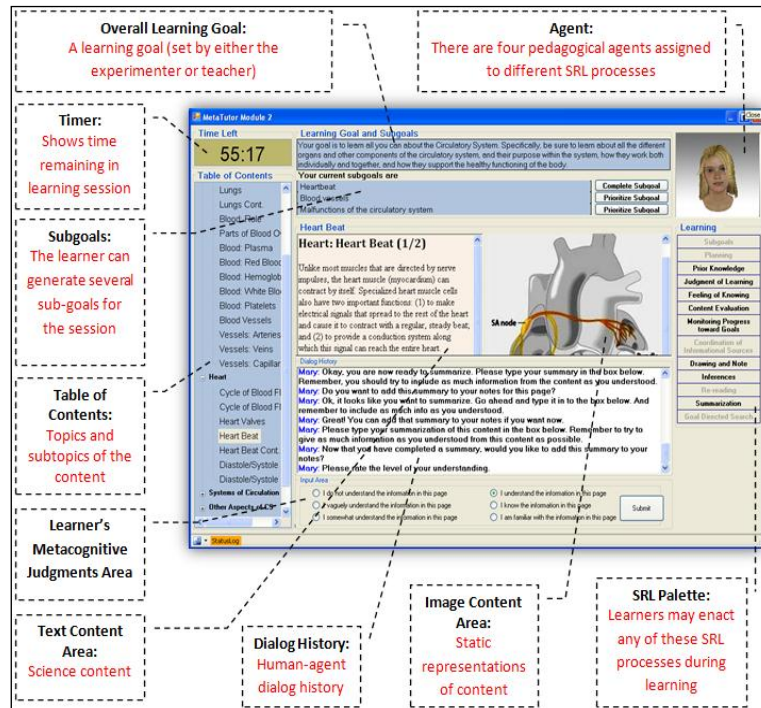
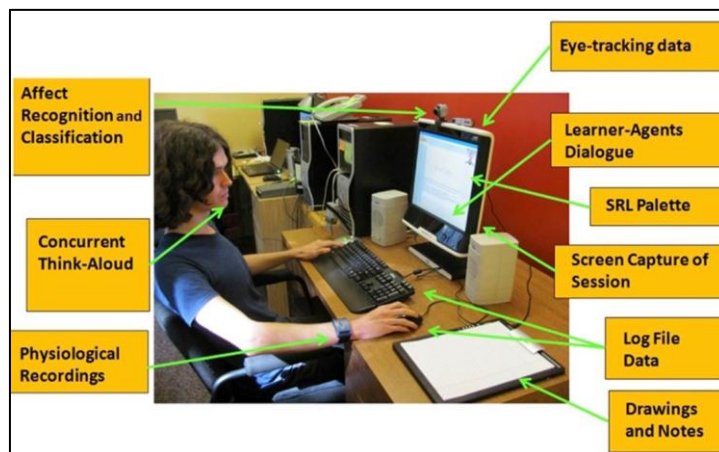**Fig. 1.** Annotated screenshot of MetaTutor

Fig. 2. Experimental set-up for the collection of cognitive, metacognitive, and affective processes during learning with MetaTutor.

The collection of these various data streams is critical to enhancing our understanding of when, how, and why students regulate or do not regulate their learning and adapt or

fail to adapt their regulatory behaviors. These data are then used to develop computational models designed to detect, track, model, and foster students' SRL processes during learning. During the presentation, we will present sample data from five different sources (i.e., concurrent think-alouds, eye-tracking, note taking and drawing, log-files, and facial detection of emotions) that exemplify the complex nature of trace data in terms of frequency of use, level of granularity, temporal sequencing, ease of inference making regarding specific macro-level SRL processes, and the role of context needed in order to understand how the trace data can augment our understanding of conceptual, measurement, and analytical issues. Lastly, we will discuss how the data are used to refine the system and pedagogical agents' behaviors to foster learners' self-regulated learning.

3   References

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